Goal 3: Reduce the major risks associated with musculoskeletal disorders in construction

Introduction

Construction work can lead to musculoskeletal disorders such as back injuries or upper arm disorders. Recognized risk factors such as high physical exertion, awkward working postures, prolonged static exertion, repetitive tasks, and vibration are common to many construction tasks and trades.

Lack of a specific reporting category for musculoskeletal disorders complicates surveillance efforts, but BLS has estimated the number musculoskeletal disorder cases by combining information on the nature of the injury (e.g. sprains, tears, back pain, carpal tunnel syndrome) with the event or exposure leading to injury (e.g. twisting, reaching, overexertion, repetition). The estimates suggest that 26% of all construction occupational injuries and illnesses with days away from work were due to musculoskeletal disorders [BLS 2003]. Construction has the second highest injury rate for days away from work of all industry sectors and studies suggest that musculoskeletal disorders in construction tend to be underreported [Rosencrance et al. 2002].

The term “ergonomics” is sometimes used to describe the approach for addressing musculoskeletal disorders. Early stakeholder interest in this subject is reflected in the decision to title the 1993 and 1995 construction conferences as a “National Conference on Ergonomics, Safety, and Health in Construction”. The 1993 conference included workshops and an exhibit of ergonomic construction tools from Sweden.

Opinions on ergonomics issues have divided stakeholders on occasion. An OSHA ergonomics regulation was overturned by Congress in 2001. A State-wide referendum defeated a State ergonomics rule with a significant construction industry focus in Washington State in 2004. Given this sensitivity, the Construction Program has emphasized the development of evidence-based methods to rigorously measure risk factors associated with such situations as awkward working postures, lifting and carrying, and stressful hand-wrist conditions. Researchers are also working to advance the measurement and understanding of the effects of vibration. Program and Center researchers have also emphasized the involvement of contractors and workers at the beginning of the research process to evaluate interventions to insure they are relevant for trades and tasks. This is also an area where researchers increasingly study the productivity of potential solutions and their diffusion into the workplace.

References

BLS [2003] Table 11 – Number of nonfatal occupational injuries and illnesses with days away from work involving musculoskeletal disorders by selected worker and case characteristics, 2001.
http://stats.bls.gov/iif/oshwc/osh/case/ostb1154.pdf

Rosencrance, J, Cook, TM, Anton, DC, and Merlino, LA [2002] Carpal tunnel syndrome among apprentice construction workers. AJIM 42(2) 107-116.

Subgoal 3.1 Reduce Musculoskeletal Disorders

A) Issue

Work-related musculoskeletal disorders (WMSD) are injuries or illnesses of the muscles, tendons, joints, and nerves caused or aggravated by work. Examples of WMSDs are: inflamed tendons or joints, elbow muscle and tissue inflammation (tennis or golfer's elbow), herniated disc, rotator cuff syndrome, carpal tunnel syndrome (CTS), and back or neck strain. Workers with jobs that include some combination of physical force, repetitive motion, awkward or static body postures, contact stress, vibration or extreme temperatures are at increased risk of developing WMSD [Bernard et al. 1997; NRC 2001]. The physically demanding nature of the work in construction, which includes manual materials handling, awkward and static postures, vibration, and a harsh outdoor environment, help explain both why strains and sprains are the most common type of injury resulting in days away from work [Schneider 2001; Center to Protect Workers' Rights 2002] and why there is high prevalence of WMSDs among construction workers [Engholm and Holmstrom 2005].

New methods were needed to study WMSDs in construction. Existing instrumentation for direct measurement of physical risk factors was designed for laboratories and was insufficiently robust for use in construction. In addition, the nature of construction work and characteristics of the construction industry create industry-specific challenges to implementing ergonomic improvements including:

- A work environment that is constantly changing.
- A mobile work force and short term jobs that limit employer incentives to invest in prevention of chronic conditions. Even where interest is present, effectiveness of interventions is difficult to measure.
- Inadequate communication among contractors and subcontractors on multi-employer worksites.
- The location of many construction tasks at floor or ceiling levels.
- The common practice of workers supplying their own hand tools, so tool interventions must often take place through individual workers rather than through employers.

B) Activities

WMSD Surveillance

In 1990, little was known about the pattern of injury and illness among construction workers. Data from BLS allowed general conclusions about rates of injury among construction workers but did not provide information on injuries among the specific construction trades. An initial effort was to establish medical surveillance systems and collect data on WMSDs specifically for construction. This was done using several approaches [Cook 1996; Cook 1997; Booth-Jones 1998]:

Construction Program and Center researchers examined National Health Interview Survey and BLS data to identify patterns of WMSDs, and to better understand the problems facing specific trades [Tanaka 1995; Hsiao 1996]. The researchers initiated a surveillance system based on construction worker injuries presenting to the emergency department at George Washington University. Program researchers learned about WMSD incidence and risk factors from cross-sectional studies among construction workers in Oregon, Massachusetts, Iowa, Ohio, and other locations. They also developed new surveillance tools, a self-reporting system for WMSD symptoms and a work history questionnaire. The key findings from the WMSD surveillance were that:

- Overall, WMSDs were more common than expected from national data.
- The prevalence of carpal tunnel syndrome (CTS) among apprentice workers was much higher than expected.
- The pattern of WMSDs varied between trades, with the trades that had more overhead work reporting a higher proportion of upper extremity disorders, and trades with more lifting and carrying tasks reporting higher proportion of back disorders.
- These WMSDs were frequently chronic, and often impacted the quality of life of construction workers.

Ergonomic exposure assessment and methods development

Assessing exposure to physical factors during variable, non-cyclic work required new ways of approaching the problem. Methods specifically designed for the construction industry were required both for the field and the laboratory. Three distinct approaches were pursued:

Qualitative exposure characterization

In Michigan, Construction Program and Center researchers evaluated 65 common construction tasks to identify and rank construction workers' exposures to seven generic WMSD risk factors, and using the same taxonomy, completed ergonomic exposure assessments of tasks in highway and tunnel construction. The assessments included ergonomic hazards of the laborer's task of "trunkman", iron work in rebar tying and in the construction of caisson cages, drywall handling and installation, and tasks that entailed stressful activities for the upper extremities [Buchholz 2003].

Observational exposure assessment

Construction Program and Center researchers developed the PATH (Posture, Activity, Tools and Handling) system. PATH is an observational work-sampling method based on the Ovako Work Posture Analyzing System (OWAS) for analyzing posture, activity, tool use, loads handled and grasp type [Fulmer 2002; Tessler 2003].

A project was conducted that evaluated construction work activities in the home building industry using the revised NIOSH Lifting Equation, the University of

Michigan Three-Dimensional Static Strength Prediction Program, and the Ohio State University Lumbar Motion Monitor Model. The program, Continual Assessment of Back Stress (CABS) added evaluation representations that highlighted the distribution of biomechanical stresses.
Construction Program and Center researchers conducted a field study involving 12 construction sites, a computer simulation, and a laboratory study evaluated worker overexertion and identified biomechanical stresses while lifting and carrying scaffold end-frames [Pan 2000].

An observational analysis (using video) and a questionnaire were used to identify hazardous aspects of drywall installation.

Quantitative exposure characterization
The Construction Program and Center developed an ergonomic dosimeter to collect continuous data characterizing carpenters' torso and the upper arm posture and kneeling frequency on working construction sites, and developed a portable EMG data logger plus a software suite to analyze the data collected. Program researchers used the dosimeter and/or data logger to study the demands of a number of construction tasks, e.g., low and upper backs of masons laying walls with lightweight and standard weight concrete masonry units, and forceful exertions among construction trade workers. One method of EMG data analysis developed specifically for use in the construction industry was clustered exposure variation analysis (CEVA), a modification of the EVA method, to allow analysis of non-cyclic work typical of construction.

Program researchers conducted laboratory simulations of gait dynamics when wearing stilts and installing drywall and hand grip forces when handling drywall. Other quantitative measurement developments included three different projects that demonstrated the feasibility of using the lumbar motion monitor (LMM) to evaluate low back injury risk for construction activities, and development of a force measurement system to measure hand contact force and estimate associated muscle activity.

Interventions

Participatory ergonomic (PE) interventions

Research has shown that a Participatory Ergonomics (PE) approach can reduce WMSD-related risk factors, and that meaningful worker participation is an important component for the success of such interventions [Rivilis et al. 2006]. A key characteristic of PE is that ergonomics problems are identified and solved at the local level with input from outside experts as needed. Since the construction industry has countless tasks with significant physical hazards, an approach limited to identifying high risk jobs and designing a specific intervention could take decades to make a difference. A programmatic approach is more likely to build company and union specific capability that can be applied to many different tasks, and to build the knowledge to use specific interventions in many locations.

Construction Center researchers undertook multiple ergonomics training activities, ergonomic job analyses, and task interventions, at the onset of the construction program. Based on this experience, Construction Program researchers developed a conceptual model guiding interventions around the locus of control, which was then applied in a PE program at a semiconductor facility being constructed by Intel in Oregon. With Program assistance, Intel provided ergonomic training for all workers, taught an ergonomics curriculum specifically designed for supervisors and health and safety staff, and hired an ergonomist to be on site for 10 hours a week to address worker or supervisor problems. We evaluated the effectiveness of this program on WMSD incidence, severity and cost during a subsequent Intel construction project.

A Washington state “Simple Solutions Group”[1] used a PE approach over a two-year period to evaluate currently available interventions (aka ‘solutions’) and develop new interventions to reduce workers’ exposure to WMSD risk factors associated with concrete placement and screeding. Ergonomic tip sheets were developed for hand trowels, concrete rake handles, rubber boots, insoles for rubber boots, stretching, body mechanics/positioning, slump and teamwork.

Construction Program researchers evaluated the effectiveness of the HomeSafe Pilot Program designed by OSHA Region VII and the Home Builders Association of Greater Denver. The study used observational methods to characterize carpenters exposure to risk factors for low back pain, implemented an intervention based on training, and measured change in injury incidence rates [Gilkey 2002; Gilkey 2003].

A Construction Program project provided new knowledge for scaffold erection and scaffold manufacturing industries to improve work techniques, scaffold components, and lifting assist devices.

The Construction Program used participatory techniques to develop a checklist for the ergonomic evaluation of non-powered hand tools [Dababneh 1999; Dababneh 2004].

The Construction Program sponsored the 2002 Mechanical and Electrical Trades stakeholder meeting to gather information regarding ergonomics interventions or ‘best practices’ by M/EI contractors and trades-people. The meeting was supported by the Plumbers and Pipefitters Union, Sheet Metal and Air-conditioning Contractor’s National Association (SMACNA), National Electrical Contractors Association (NECA), and regional trade and labor associations.

In March 2004, the Construction Program and Center sponsored a meeting titled *Exploring the Use of Best Practices for Prevention of Musculoskeletal Disorders in the Masonry Trades.* Co-sponsors included the International Council of Employers of Bricklayers & Allied Craftworkers, the International Union of Bricklayers and Allied Craftworkers, the Laborers Health and Safety Fund of North America, and the Mason Contractors Association of North America.

Training and Education Programs
The United Brotherhood of Carpenters (UBC) developed and evaluated an ergonomics training program for apprentice and journey status carpenters [Coleman and Narayan, 1995]. The program aimed to reduce WMSDs through

[1] Build It Smart, AGC of Washington, Western Washington Cement Masons Training Center, Laborer’s Health and Safety Fund of North America, University of Washington Department of Environmental Health and Occupational Health Sciences and the StewartPrezant Ergonomics Group

training and identification of ergonomic stressors associated with cumulative trauma disorders (CTDs) in selected carpentry tasks [Albers et al, 1997]. The Hardhat Ergonomists (HHE) training program was developed by Construction Center researchers and fully implemented with separate funding from the Commonwealth of Massachusetts Workforce Training Fund. The national *Smart Mark* training initiative was launched in 1998 by the Building Trades Department, with support from the Construction Center (see subgoal 4.3). A 1-hour module on ergonomics is included in the training program.

Evaluation of specific tool/equipment interventions
Ergonomic evaluations of five activities and 12 different tools were completed by the Program between 2002 and 2004. We focused the evaluations in four high risk construction activities: working overhead, working at foot level, hand-intensive work, and concrete reinforcement and placement operations. A study was conducted on a freeway bridge construction site using a data logger and goniometers to characterize ironworkers' wrist posture and wrist motion when tying rebar. Construction Center researchers also evaluated the benefit of a therapeutic exercise as an intervention to modify motion and muscle activity alterations in construction workers with shoulder symptoms [Ludewig 2002].

C) Outputs and Transfer

See Appendix 3.1 for full list of outputs and transfers

Surveillance
Construction Program and Center researchers produced 25 peer reviewed publications related to WMSD surveillance findings and transferred findings via 9 presentations.

Ergonomic exposure assessment and methods development
Construction Program and Center researchers produced 93 scientific outputs and shared results via 30 presentations at scientific conferences. These outputs describe the research instruments, tools, and software described in the approach section, including the portable EMG data logger and dosimeter (see Anton; Bhattacharya); CEVA (see Anton); CABS (see Mirka) application of the lumbar motion monitor (see Mirka; Hess); the PATH method (see Buchholz; Fulmer) decision support tool (see Nussbaum); optimal tool design (see Kong and Lowe); and validation of questionnaires for surveillance of MSDs among construction workers (see Lemasters; Rosecrance). Sixty-three publications evaluating MSD risk factors in various settings were developed by Construction program and center researchers.

Intervention/prevention research
Construction Program and Center researchers developed user-friendly materials to raise awareness about MSD issues and to describe effective interventions and approaches. For example, the Construction Center produced 28 articles on

ergonomics for the two CPWR newsletters, *Impact* and *On Center* Construction Center researchers at the University of Massachusetts, Lowell published eight issues of *Bright Ideas: Construction workers' health and safety innovations on the job:* Bright Idea #1: Spatula; Bright Idea #2: Post & Bracket Railing System; Bright Idea #3: Pipe Wrench Stand; Bright Idea #4: The "Binford Crab" Clamp; Bright Idea #5: Crane Mirror; Bright Idea #6: Trailer Lift; Bright Idea #7: IronWorker's Box; Bright Idea #8: McGovern Lever. In addition, 29 technical reports specific for ergonomics on the Central Artery/Tunnel project (CA/T), (aka The Big Dig), were produced. These documents were distributed to contractors and trades on the CA/T project, and to the CA/T Research Policy Advisory Committee (RPAC), which consists of representatives from the Massachusetts Highway Dept, Bechtel Corporation, the Big Dig contractors and the building trades unions. They also distributed a quarterly publication, *On The Beam*, about the health hazards of construction and the particulars of their current research, was published 13 times in six years to a mailing list of about 2400 hundred construction workers and related industry people.

The Washington state Simple Solutions Group developed 12 *Sensible Solutions* for construction ergonomic hazards commonly found in the placement and finishing of concrete.

The Construction Program produced several documents that present the results of intervention evaluations:

- *NIOSH Proceedings of a Meeting to Explore the Use of Ergonomic Interventions for the Mechanical and Electrical Trades.* NIOSH 2006 NTIS PB2006-14081 http://www.cdc.gov/niosh/docs/2006-119/pdfs/2006-119.pdf It includes descriptions of construction contractors and craft workers use of ergonomic interventions during the installation of electrical, heating/air conditioning and piping systems. Many construction stakeholders requested copies (3700 copies printed and a second printing has been requested), including the United Association of Plumbers (350), International Brotherhood of Electrical Workers (320) and Sheet Metal Occupational Health Institute Trust (530). A second printing of the document (7500) was completed during 01-07. The document was also distributed at the Oregon Governor's Safety Conference (02/07), the Construction Safety Conference and Exposition in Chicago (02/07), and to industry stakeholders.

  Preventing Injuries from Installing Drywall NIOSH-- Publication No. 2006-147: *The construction program drywall installation project resulted in recommendations on the least stressful drywall lifting and handling methods to reduce the biomechanical hazards resulting from overexertion and falls. Thousands of copies have been distributed.*

Easy Ergonomics – A Guide to Selecting Non-Powered Hand Tools [NIOSH Publication No. 2004-164] was produced jointly by construction program researchers and Cal/OSHA. As of August, 2006, nearly 19,000 hard copies of the document had been distributed. Through September, 2006 the NIOSH website is averaging approximately 300 hits/month on the page linking to this document and 190 actual downloads/month. In August 2006, Cal/OSHA also released a Spanish language version of this document.

Health Hazard Evaluation report: HETA-2003-0146-2976, Genesis Steel Services, Inc., Baltimore, Maryland NIOSH evaluated the comparative risk that reinforcing ironworkers have for developing back and hand disorders as a result of hand-tying reinforcement steel on concrete bridge decks when using traditional and power rebar tying methods.

The manufacturer of a concrete reinforcing steel tier asked construction program researchers to present a seminar related to ergonomics and the rebar tying intervention HHE (HETA 2003-0146, Genesis Steel Services, Inc.) at their national meeting of tool retailers (August, 2004).

D) Intermediate Outcomes

Surveillance

Information on patterns of WMSDs, as cited above, has been used by other researchers and organizations. Some highlights include the following:

Lipscomb H, Dement J, Loomis D, Silverstein B, Kalat J [1997]. Surveillance of work related musculoskeletal injuries among union carpenters. Am J Ind Med *32*(6):629 640. (Cited by 17)

Merlino L, Rosecrance J, Anton D, Cook T [2003]. Symptoms of musculoskeletal disorders among apprentice construction workers. Appl Occup Environ Hyg *18*(1):57 64. (Cited by 7)

Rosecrance J, Cook T, Zimmermann C [1996]. Work-related musculoskeletal symptoms among construction workers in the pipe trades. Work *7*(1):13 20. (Cited by 7)

Schneider S [2001]. Musculoskeletal injuries in construction: A review of the literature. App Occ Environ Hyg *16*(11):1056 1064. (Cited by 9)

Welch L, Hunting K, Nessel-Stephens L [1999]. Chronic symptoms in construction workers treated for musculoskeletal injuries. Am J Ind Med *36*(5):532 540. (Cited by 11)

Ergonomic exposure assessment and methods development

Information on hazardous exposures, and methods of assessing those exposures, as discussed above, has been used by other researchers and organizations. Scientific publications derived from this work have impacted the research community, as evidenced by the construction program publication “Optimal cylindrical handle diameter for grip force tasks” [Kong and Lowe 2005] being ranked in the top five most frequently downloaded articles in the *International Journal of Industrial Ergonomics* in 2005. Some additional highlights include the following:

- *NIOSH Proceedings of a Meeting to Explore the Use of Ergonomic Interventions for the Mechanical and Electrical Trades* was cited in: Karwowski E. and Marras WS, Eds. (2006). Interventions, Controls, and Applications in Occupational Ergonomics, CRC Press, Boca Raton, FL. Users of the publication include OSHA, The National Utility Contractors Association, and the National Safety Management Society. The publication has been referenced on numerous websites, including the International Labour Organization (ILO), Lawrence Livermore Laboratory, German Neuerwerbungen der Bibliothek der BAuA, Italian SicurWeb.

- *Easy Ergonomics – A Guide to Selecting Non-Powered Hand Tools* (NIOSH Publication No. 2004-164) was cited in 102 references (Google search 01/30/07), including organizations in the US, Canada, Brazil, Japan, and Europe (Spain, UK, Switzerland), health and safety professional associations (American Society of Safety Engineers, National Safety Management Association), state/provincial government agencies (including Washington, West Virginia, Florida, Connecticut, Iowa, and British Columbia), educational institutions (University of South Florida and UCLA), a military newsletter (US Army Industrial Hygiene Information Summary), trade union and trade associations (Laborers’ Health & Safety Fund, Greater Detroit Building Trades Council, Center to Protect Workers’ Rights), and health and safety resource guides (ErgoWeb, Bureau of Legal Reports, BNA OS&H Reporter, Occupational Hazards).

- *Health Hazard Evaluation report: HETA-2003-0146-2976, Genesis Steel Services, Inc., Baltimore, Maryland* The rebar-tying HHE has been reported in eight concrete sector magazines, and on the International Association of Bridge, Ornamental, and Reinforcing Iron Workers union web page at http://www.ironworkers.org/ht/d/sp/i/1932/pid/1932.

  Many organizations have posted links to the *Easy Ergonomics* publication, or have provided a summary of the document embedded in their own information materials. These include: ErgoWeb; Ohio State University Institute for Ergonomics; Agricultural Safety & Disaster Management Program. Department of Agricultural and Biological Engineering, University of Florida; National AgrAbility Project; Lawrence Livermore National Laboratory; Farm Employers Labor Service; U.S. Army Center for Health Promotion and Preventive Medicine; University of Nebraska Environmental Health and Safety; University of Wisconsin Milwaukee; International Association of Machinists and Aerospace Workers; National Telecommunications Safety Panel; ILO; and the National Safety Management Society. The *Easy Ergonomics* booklet has also been distributed by trade associations to its members including the American Subcontractors Association which distributed the booklet at a 01-06 meeting.
  (http://www.osha.gov/dcsp/alliances/regional/reg4/asa_al_annualreport2006.html).

- Davidson B, Madigan M, Nussbaum M [2004]. Effects of lumbar extensor fatigue and fatigue rate on postural sway. European J App Physiol *93*:183 189. (Cited by 3)

- Zimmermann C, Cook T [1997]. Effects of vibration frequency and postural changes on human responses to seated whole-body vibration exposure. Inter Arch Occ Environ Health *69*:165 179. (Cited by 8)

The construction program influenced other organizations to develop materials increasing the awareness of WMSDs and 'best practices' for prevention. For example:

- The Associated General Contractors (AGC) contracted the Zurich Services Corp. to develop the 'Soft Tissue Injury Prevention' training program.
- The Hartford Loss Control Department published 'Preventing MSDs in Construction' The document includes information related to MSD hazards and interventions derived from construction program work and was based on construction program research.
- The Construction Ergonomics Checklist was published in *Contractor News,* by Liberty Northwest Insurance and is in press in *Roofing Contractor.*
- At least five international construction unions used construction program materials in newsletters and magazines between 1994 and 2002.

Methods development -- The questionnaire for surveillance of MSDs among construction workers has been used by other researchers [2] and has been translated into several languages. The portable data logger [3] and the PATH

[2] Field evaluation of a continuous passive lumbar motion system among operators of earthmoving … M Viswanathan, MJ Jorgensen, NK Kittusamy - International Journal of Industrial Ergonomics, 2006
Musculoskeletal symptom survey among cement and concrete workers D Goldsheyder - Work, 2004

[3] R01-OH007945-04 NIOSH Prospective Study of UEMSD and Physical Job Stressors (Gerr F - PI, Anton D - Co-PI). Logger is/was used for workplace measurement of exposure to forceful exertions of the hand/wrist and upper back of workers in an appliance manufacturing facility.
Masonry Ergonomics Best Practices (Anton D - PI). Logger was used to measure low and upper back EMG of masons laying walls with lightweight and standard weight CMUs.
A Comprehensive Ergonomic Assessment of a Respiratory Intervention for Tuckpointing Workers, Heartland Center for Occupational Health and Safety Pilot Grant (Collingwood S - PI, Anton D - faculty advisor, Co-Investigator). Logger used at masonry worksites to evaluate muscle activity while using shrouded and unshrouded tuckpoint grinding.
A Comparison of Exposure to Risk Factors in Construction Trades with Contrasting Prevalence of Carpal Tunnel Syndrome, Heartland Center for Occupational Health and Safety Pilot Grant (Anton D - PI).
The electromyographic sampling duration required to precisely estimate individual exposure to forceful exertions, Heartland Center for Occupational Health and Safety Pilot Grant (Fethke N – PI, Anton D - faculty advisor, Co-Investigator)
Study of forceful exertions among ultrasonographers. Alysha Meyers worked in Poland with Patrycja Krawczyk-Adamus, MD, PhD, Researcher, Department of Work Physiology and Ergonomics, Nofer Institute of Occupational Medicine, Lodz, Poland.
Pilot study of response time during simulated automobile crashes. Study conducted at the University of Minnesota Driving Simulator
The logger will be used by Katrina Maluf, PhD, PT, at the University of Colorado at Denver and Health Sciences Center to collect pilot data for her Foundation for Physical Therapy Grant, American Physical Therapy Association, Evaluation of a Novel Biofeedback Approach in Patients with Work-related Neck Pain.

observational exposure assessment method in construction [4] are being used in other research, both in construction and other industries.

Intervention/prevention research

The UBC and Joiners has continued to support ergonomics awareness training for apprentices and journey status carpenters. For example, during 2002 – 2006, the UBC Training Center in Las Vegas, NV, hosted 61 apprentice instructors in ten ‘train the trainer’ classes to enable them to teach the ergonomics awareness class. In addition, during a six-month period in 2006 (February – June), 1528 ergonomics awareness education manuals were ordered by the apprentice training centers. Training center staff reported that an average 250 manuals are ordered by local apprenticeship programs each month. Finally, the UBC has committed to updating the ergonomics awareness training manual during 2007. Over 60,000 construction workers are now trained in *Smart Mark* annually, and over 4,000 building trades union instructors are now certified to teach the *Smart Mark* training program. (We do not have specific information of how frequently the 1-hour module on ergonomics is included in the training program; see chapter 3 subgoal 4-3 for more details.)

[4] Four UML doctoral dissertations on research using PATH in construction; 1 UML doctoral dissertation using PATH in a study in nursing homes in Washington state; see SHARP Technical Report 61-05-2003, called “Getting to Zero…”.
NIOSH staff used PATH to characterize exposure of warehouse workers, and in a study on flight attendants.
The New York Center for Agricultural Medicine and Health used PATH in studies of apple harvesting, fishing., and dairy farming
UML researchers used PATH to characterize ergonomic exposure to a broad range of hospital occupations
UConn researchers used PATH to analyze ergo exposures of submarine manufacturers, and of dental hygienists.
PATH is being used to quantify exposures as part of an intervention effectiveness study in preventing injuries in nursing staff of nursing homes, and to characterize knee exposures in Carpenters in a 3-year epidemiologic study.

Construction program researchers submitted an invention report (CDC EIR I-040-05 "*A System for the Characterization of Hand Contact Force*") for a system that measures hand contact force. This technology received a patentable recommendation in the review by Foresight Science and Technology Group. Construction program researchers have been exploring opportunities for a Cooperative Research and Development Agreement (CRADA) and /or commercial licensing of the technology. The technology has been applied in several other studies and projects within the MSD program.

The eight issues of *Bright Ideas: Construction workers' health and safety innovations on the job* were collectively viewed 3950 times on eLCOSH between May 1, 2006 and May 1, 2007. The most frequently viewed ideas were #6, Trailer Lift (678 hits) and # 3, Pipewrench Stand (617 hits). In addition, the UML continues to get approximately 100 requests per year for *Bright Ideas*.

The Laborers National Health and Safety Fund provides a link to the 12 Build It Smart *Sensible Solutions*. http://www.lhsfna.org/index.cfm?objectID=443C54F5-D56F-E6FA-9C77F0C03D2A962D.

After he completed his degree, a graduate student working with construction center researchers served as director of research and development for hand tools for Fiskars. His input was instrumental in the design of a range of products with improved ergonomic attributes, including the Data-comm Shears which were specifically designed for use in the construction industry. Through the work of this ergonomist at Fiskars, the company benefited from knowledge of tool design developed under the construction program.

After the research support for the ergonomics program at Intel from the University of Oregon ended, Intel adopted the university program and continued a site-based ergonomic effort. They continue to use this program on Intel sites in the United States and on international construction projects. Intel describes the success of the program on their web site in an area titled: <u>Building Excellence Through Ergonomics</u> (https://supplier2.intel.com/EHS/BETE/betemain.htm). Construction center researchers evaluated the effectiveness of the participatory ergonomics program on MSD incidence, severity and cost on a large construction project. As with ergonomic intervention programs in other industries, the research found an increase in reported MSDs, but a significant decrease in duration per claim and cost per claim. Costs were reduced 25% and 36% when compared to similar construction projects by the same company in two other areas of the country.

Construction Center researchers worked with Midwest Tool and Cutlery, a company making hand tools for the construction industry, both presenting the results of their aviation snips study to the Board of Directors and evaluating a re-design of the snips. Based on strong laboratory evidence confirming a reduction in risk factors associated with the construction program hand tool design guidelines, tools are being produced and marketed that incorporate the construction program design features. Exposure of construction workers to risk factors will be reduced. The CEO at Midwest Snips reported recently that:

1. The upright snips are selling well.
2. The snips have a wider appeal in more markets than Midwest originally expected. They thought they would sell primarily to sheet metal workers, but siders and electricians are also purchasing them.
3. The snips are now sold at Sears and Home Depot.
4. The company received several letters of appreciation from end users.

The company has continued to develop additional hand tools with improved design to reduce the physical stress on the hand and is currently collaborating with Construction Program researchers to evaluate the effectiveness and worker acceptability of two ergonomically designed hand tools they manufacture. (http://www.midwestsnips.com/).

Capacity building for future research and intervention

Construction ergonomics programs at several universities were developed and/or supported in part by Construction Program funding (University of Cincinnati, University of Iowa, University of Oregon, University of Massachusetts at Lowell). Graduate students from these programs have gone on to develop research capacity in ergonomics at 10 other institutions[5]. These university programs also supported development of ergonomics research programs in other industries, with graduate student training and with availability of laboratories for research. The research projects conducted by the construction center researchers at the University of Oregon, and their work with Intel, created a synergy in the greater Portland area for development of new approaches to ergonomics in construction. There was continued collaboration between Intel, its subcontractors, the unions and the University of Oregon. Through the Intel project, many smaller contractors were involved in the ergonomic training program, and in addition to their work on this specific construction project, the University of Oregon worked with a range of contractors in the greater Portland area. The increased sophistication of contractors in the metropolitan area led to the Construction Ergonomic Initiative (CEI) convened by Oregon OSHA, and the Greater Portland Construction Partnership, which was stimulated by Intel. The CEI developed a website for construction ergonomics http://www.cbs.state.or.us/external/osha/consult/ergonomic/const_ergo.html).

Based on work with the contractors in the CEI, OSHA provided consultation to a wide range of construction companies. This construction partnership organized a

[5] University at Buffalo, The State University of New York, St. George's University, University of Minnesota, Colorado State University, University of California at San Francisco, Washington University, St. Louis, MO, University of Cincinnati, North Carolina State University

conference in November of 2006: The Next Generation of Safety in Construction; 120 contractors attended. http://ccee.oregonstate.edu/nexcon/

E) External factors

There is an absence of a legal/regulatory framework for addressing WMSDs in all states except Washington and California. The Washington State ergonomics standard was rescinded in 2004. Anticipation of the standard, however, generated a significant amount of activity in Washington and neighboring Oregon, directed at identifying WMSD risk factors and identifying and evaluating potential control technology to reduce exposures to the risk factors. The weaker, but sustained, California ergonomics standard raised awareness among contractors and trades people in the state.

Construction trade associations demonstrated significant trepidation and, in some cases, outright hostility to acknowledgement of WMSDs as a legitimate safety and health issue. The OSHA ergonomics standard, rescinded in 2001 shortly after being promulgated, served to further polarize stakeholder perspectives. While it was possible to collaborate with local trade associations, with few, (i.e., Sheet Metal and Air Conditioning Contractors National Association, Independent Electrical Contractors, Masonry Contractors Association of America, and National Electrical Contractors) exceptions, national construction trade associations have been reluctant to cooperate.

Conducting research activities on working construction sites presents many difficulties not experienced in other fields of research. Of significant importance is the dynamic nature of the activities, which can lead to both advances and delays in the execution of the tasks of interest to the researcher. Other difficulties include:

- Many construction contractors and workers consider risk part of the industry.
- Building collaborative relationships between university researchers and construction companies was difficult. For example it took several years to develop a memorandum of understanding on the Big Dig that allowed the researchers access to the construction sites; in other areas of the country it has also taken time for the academic researchers to build collaborative relationships even with a small number of contractors.
- Construction solutions are job and task specific. For example, a solution to redesign installation of ceiling panels in tunnel construction on the Big Dig is not a solution that could be readily applied to the next project . That contractor may never use that specific design again nor is there a mechanism to disseminate this specific tasks solution to other contractors. The building of understanding and capacity by specific contractors once they understand that ergonomic solutions requires ongoing monitoring and participation with the workers. Transferring this understanding from one

contractor to another is more complicated and time consuming than simply transferring a specific tool or a work practice.

- Contractors are reluctant to share successful programs with other contractors because they are competing with those contractors for work. An effective PE program, for example, requires development of training materials, and training capacity, within an organization. Once a contractor has acquired this capacity, and is realizing benefits, that contractor would prefer to retain that market advantage.
- Contractors can acquire new knowledge about successful ergonomic programs from consultants and university research programs. However, the University of Oregon research documented that most construction contractors look for new information within the industry rather than from outsiders. This appears to be an issue for smaller companies, which are the great majority of construction companies
- Contractors in Oregon were paying attention to ergonomics in part because they anticipated passage of an ergonomic state standard similar to the one in Washington. The Washington ergonomics standard was repealed after a ballot initiative. This is an important external factor that led to decreased ergonomic emphasis by Oregon OSHA, and subsequently throughout the northwest.

F) What's ahead?

The NIOSH document, *Simple Solutions: Ergonomics for Construction Workers* will be published in 2007. The document will include general descriptions of construction related risk factors for WMSDs and 20 individual tip sheets describing 'best practices' for reducing exposure to risk factors.

We identified overhead drilling and other overhead work as an important hazard in the mechanical and electrical trades. Based of the work described above, a current project at the University of California at San Francisco is developing an intervention for overhead drilling in construction; many of the participating contractors are ones who had previously worked with construction center researchers. In a complementary project, field and laboratory evaluation of a stand to support overhead use of a rotary impact hammer drill is also planned.

Continuing the successful collaboration with Midwest Tools, studies are being completed that investigate the effectiveness and worker acceptability of ergonomic hand tool design of 2 two-handle cutting tools used by sheet metal workers (e.g. snips, cable cutters). Prototype sheet metal tools with reduced handle span and more rounded handle contour have been constructed by Midwest Tools; these designs are anticipated to reduce the muscular loading and localized hand pressure that causes user discomfort and contributes to soft tissue disorders.

A program to diffuse ergonomic solutions through the masonry industry is in progress. It includes assessment of actual use patterns of effective engineering controls and work practices, and identification of barriers to use. Two studies are being completed that assess mason tenders' low back loading. One study is comparing the difference in loading during the handling of full-weight (97 lbs.) and half-weight bags of Portland cement bags. The second study is assessing mason tenders' low back loading when conducting different tasks on residential and commercial construction sites.

A study to assess the impact of social and economic impact of injury, including WMSD, among roofers is in process.

Information on solutions to ergonomic and other hazards is being included in CPWR Construction Solutions.

A complementary program to disseminate other ergonomic solutions in construction is being conducted by the University of Oregon.

A memorandum of understanding between NIOSH and Sungkyunkwan University (Yong-Ku Kong) has been finalized and the two organizations will continue, in a more formalized partnership, with development of technologies quantifying hand force exertion and interventions to reduce this physical stress in construction work.

To further the work of the construction program on manual concrete construction methods (e.g., concrete screeding/leveling and rebar tying), two social marketing plans for contractors have been developed. The brochures have been evaluated by 6 focus groups. These brochures will be modified according to the contractor feedback and distributed to concrete contractors during FY2008.

The NIOSH Construction Program developed a draft strategic goal to address musculoskeletal disorders in construction workers and the issue was also selected by the NORA Construction Sector Council for additional attention over the decade.

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Appendix 3.1

WMSD Surveillance

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Ergonomic exposure assessment and methods development

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Subgoal 3.2 Disorders Associated with Excessive Exposure to Vibration

A) Issue

Construction workers are exposed to upper limb vibration through the use of powered hand tools such as chipping hammers, grinders, chainsaws, rock drills, road breakers, and riveters. While there are no published estimates of how many construction workers have regular exposure to vibration, a United Kingdom study reported that 63% of construction workers had weekly exposures [Palmer 2000]. Excessive vibration exposure can result in damage to soft tissues and Hand-arm vibration syndrome (HAVS) is estimated to affect more than a million exposed workers in the construction, mining, and manufacturing sectors. The most well-known component of HAVS is termed vibration-induced white finger (VWF). Although HAVS has been studied for more than 80 years, the mechanisms of the syndrome are not sufficiently understood. Whole body vibration exposures are a related vibration concern which can affect workers operating construction vehicles. Disorders associated with vibration are classified with musculoskeletal disorders (MSDs).

Early stages of vibration syndrome are characterized by tingling or numbness in the fingers. Temporary tingling or numbness during or soon after use of a vibrating hand tool is not considered vibration syndrome. To be diagnosed as vibration syndrome, the neurologic symptoms must be more persistent and occur without provocation by immediate exposure to vibration. With continuing exposure to vibration, the signs and symptoms become more severe and the pathology may become irreversible.

NIOSH research on vibration predates the Construction Program. Early NIOSH publications such as a 1983 Current Intelligence Bulletin (CIB) titled *Vibration Syndrome* described the basic issues, available precautions, and data gaps. For example, the CIB stated: "Despite considerable research, little is known about the physiological basis of vibration syndrome or which specific vibration parameters, such as acceleration, frequency spectrum, or energy transferred to the hand, are the most necessary to control. The progressive stages of vibration syndrome arise from the cumulative effect of vibration-induced trauma to the hands from the regular, prolonged use of vibrating hand tools in certain occupations." [NIOSH 1983]

In 2001, the National Academies published a report on MSDs and the workplace [NA 2001] which identified many gaps and topics of surveillance, categorization, epidemiology, and basic research that should be addressed. From this analysis, NIOSH developed a program to assess which characteristics of vibration exposure are associated with an increased risk of developing vibration-induced injury and to devise the necessary testing systems to evaluate the vibration exposure due to specific hand tools and work patterns.

The Construction Program supports cross-cutting, in-house lab research targeting basic health effect, exposure assessment, and methodology data gaps. The intention is to provide the scientific foundation for the identification and measurement of relevant vibration characteristics to enable the development of reduced vibration tools and equipment such as anti-vibration gloves.

B) Activities

Construction Program health scientists and engineers are addressing the following research activities:

Methods research

Construction Program researchers developed methods needed to support health effects studies. Methods research has targeted improved measurement of vibration, development of lab equipment that can characterize and replicate the vibration characteristics of a given tool, and development of methods to estimate the vibration isolation performance of anti-vibration gloves.

Health effects research

The overall approach to addressing these research needs has been to use animal models to assess which characteristics of vibration exposure (e.g., frequency, amplitude, duration, force) are associated with an increased risk of developing vibration -induced neuropathies, vascular injury and muscle damage. By understanding the cellular responses of soft tissues to vibration exposure, we can determine what types of vibration exposures are most damaging, and can establish dose-response relationships between vibration and soft tissue injuries.

We are building on this work to develop physiological or biological tests for the early detection of vibration-induced disorders. Dose-response data can be used to improve existing guidelines limiting vibration exposure and guidelines describing methods for diagnosing vibration-induced injuries. Ultimately, these data can be used to support more effective prevention strategies (e.g., criteria for improved tool designs and improved anti-vibration gloves) and development of treatment strategies.

Anti-vibration gloves have been introduced as a personal protective measure to help reduce the severity of vibration exposure. These gloves are made of resilient materials or air bladders which are designed to attenuate the vibration transmitted to the hands while operating hand-held power tools. The vibration isolation performance of a particular anti-vibration glove depends upon the nature of tool vibration (magnitude and frequency range), visco-elastic properties of the glove material, arm posture, and magnitudes of hand-grip and feed forces.

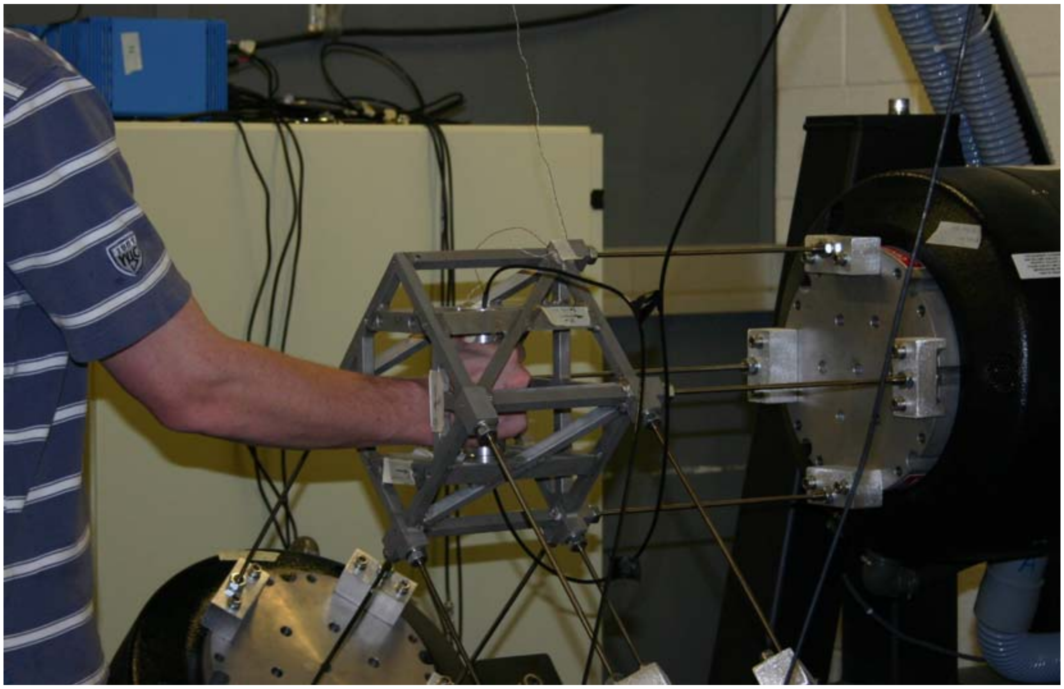
In addition to hand-arm vibration, we are establishing direct cause and effect relationships between segmental and whole body vibration and associated musculoskeletal disorders.

Construction Program vibration researchers are coordinating with other vibration investigators and stakeholders via mechanisms such as conferences, standard-setting bodies, and serving as journal peer-reviewers.

C) Outputs and Transfer

(Appendix 3.2 includes a complete list of vibration-related outputs and transfer activities)

Construction Program researchers actively disseminate methods and health effects research findings. Since 2001, more than 60 peer-reviewed journal articles have been published. Examples include: “Estimation of tool-specific isolation performance of anti-vibration gloves” [Rakheja et al. 2002]; “Estimation of the biodynamic force acting at the interface between hand and vibrating surface” [Dong et al. 2005]; “Distribution of mechanical impedance at the fingers and the palm of human hand” [Dong et al. 2005]; and “Relationship between the grip, push and contact forces between the hand and a tool handle [Welcome et al. 2004].



Transfer activities include organizing and hosting the 1st American Conference on Human Vibration, Morgantown, WV in June 2006. A total of 140 researchers and stakeholders attended the meeting to exchange findings. Construction Program researchers have made more than100 presentations at various meetings and conferences since 2001 and have been specially invited to give seminars and courses. For example, an invited speech titled “Biodynamics of hand-arm system and modeling methods” was provided to the University of Kansas Department of Mechanical Engineering in 2006, an invited course on the “Biodynamics of hand-arm system and vibration-induced health effects” was presented to the Japanese counterpart of NIOSH in 2005, and requested vibration measurement training and consultation were provided to U.S. Navy personnel in 2003.

Construction Program researchers also share knowledge by responding to vibration-related questions from stakeholders and the public (more than 40 inquiries since 2001) and by serving as subject matter reviewers for about 20 manuscripts per year for vibration-related journal articles[6] and assisting with vibration-related Health Hazard Evaluation requests.

Lastly, Construction Program researchers transfer findings via direct participation in a number of consensus standard-setting groups that address vibration (additional details provided below).

[6] Examples include: Journal of Biomechanics, Ergonomics, International Journal of Industrial Ergonomics, Medical Engineering Physics, Journal of Sound and Vibration, Industrial Health, Journal of Occupational and Environmental Medicine, American Journal of Physiology.

D) Intermediate Outcomes

Research findings are used by other researchers. For example, the four peer-reviewed journal articles listed as examples in the outcomes section above have been cited by other researchers 74, 51, 29, and 10 times, respectively, according to Google Scholar.

Involvement of Construction Program researchers and use of research findings (including the specific studies mentioned in the outputs section) have led to development and revisions of several national and international consensus standards as described below:

- ISO 5349 - Mechanical vibration -- Measurement and evaluation of human exposure to hand-transmitted vibration. Dr. Dong served as the vice chair of the U.S. Technical Advisor Group for this international standard, and coordinated review. It is an essential International Standard on hand-transmitted vibration exposure and risk assessment and provides the basis of the vibration measurement and evaluation used in all the tool test standards. All the tool vibration levels claimed by the tool companies are measured using these standards [ISO 5349, 2001].

- ANSI 2.70 - Guide for the Measurement and Evaluation of Human Exposure to Vibration Transmitted to the Hand. Construction Program researchers participated in the development of this ANSI standard, which is the more recent American standard counterpart to ISO 5349 [ANSI 2.70, 2006].

- ISO 10068 - Mechanical vibration and shock-free, mechanical impedance of the human hand-arm system at the driving point. Dr. Dong has also been the international project leader for the review and revision of ISO 10068 which is the standard for the biodynamic response of the hand-arm system. The ISO 10068 standard is based on measurements of the mechanical vibration and shock-free, mechanical impedance of the human hand-arm system at the driving point [ISO 10068, 1998].

- ISO 8662-2 - Hand-held portable power tools – Measurement of vibration at the handle – Part 2: Chipping hammers and riveting hammers; and ISO 8662-7 - Hand-held portable power tools – Measurement of vibration at the handle – Part 7: Wrenches, screwdrivers and nut runners with impact, impulse or ratchet action. Construction Program researchers are also working on the experimental study for the revision of the hand-held portable power tools standards for both of these standards [ISO 8662-2, 1999; ISO 8662-7, 1999].

  ISO 10819, Mechanical vibration and shock -- Hand-arm vibration -- Method for the measurement and evaluation of the vibration transmissibility of gloves at the palm of the hand. Construction Program researchers are currently involved with updating the standard [ISO 10819, 1996].

- ISO/DIS 15230: Definition and guidelines for the measurement of the coupling forces for operators exposed to hand-arm vibration. The studies of hand vibrations have also resulted in significant impact on the development of the new standard on hand and force measurements [ISO/DIS 15230, 2005]. The main body of the standard was substantially revised based on comments and prior research studies of Construction Program investigators.

These consensus standards in turn are being used by governments, tool manufacturers, and safety and health professionals to reduce vibration exposures. While there are no OSHA standards governing vibration standards for U.S. construction workers, the European Union has established a Human Vibration Directive [EU 2002]. The standard sets minimum requirements for the health and safety of workers exposed to vibration. It specifically cites ISO standards which Construction Program researchers helped develop (ISO 5349, for example). It is expected that injuries from exposure to vibration will be reduced as these minimum standards for the control of vibration risks are adopted more widely. Tool manufacturers are using these standards to develop new product lines and there is increasing awareness of vibration reduction as a design objective. This has been demonstrated by recent trade press announcements and articles (See Vibration Air Tools from Honsa Ergonomic Tools; Makita AVT Technology; Masonry Magazine Power Tools as examples of evidence of these changes.)

E) External Factors

Negative external factors include generally low awareness of chronic vibration disorders among construction workers and contractors and the lack of any OSHA regulation for vibration.

Positive factors include the high level of consensus standard activity among vibration researchers and stakeholders. Implementation of the European Union Human Vibration Directive is another positive factor, given that many U.S. tool manufacturers sell products in Europe and vice versa.

The age demographics of the U.S. workforce will be undergoing a significant shift toward older workers in future years. The Construction Program has undertaken a number of studies that address some concerns associated with an older workforce. A major emphasis in future studies of MSD will be to identify the work patterns and regimes which may predispose older individuals to injury. A second area of emphasis is on the factors that affect muscle regeneration and how these may be supplemented.

F) What's Ahead?

Construction Program researchers will continue the basic studies on the segment and whole-body vibration exposures. However, the applications of the knowledge and results to develop effective preventive methods and technologies will be emphasized. Involvement with consensus standard-setting organizations will also continue.

Construction Program researchers are planning to develop a "Workplace Solutions" document to provide guidance on the selection and use of anti-vibration gloves.

A Program supported study is underway at Virginia Tech looking at both vibration and noise associated with chipping hammers. The study aims to characterize the vibration and noise sources, evaluate control options and to develop viable solutions working with two tool manufacturer partners.

The Construction Program has a number of studies which address some of the concerns associated with an older workforce. A major emphasis in future studies of MSD will be to identify the work patterns and regimes which may predispose older individuals to injury. A second area of emphasis is on the factors that affect muscle regeneration and how these may be supplemented.

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Appendix 3.2

Peer Reviewed Publications

Dong RG, Wu JZ, Welcome DE, McDowell TW (in press). A new approach to characterize grip force applied to a cylindrical handle. Medical Engineering and Physics.

Cutlip RG,.Baker BA, Geronilla KB, Kashon ML, Wu JZ, (In press) The influence of velocity of stretch-shortening cycles during a chronic exposure on muscle performance: Age effects. Applied Physiology, Nutrition and Metabolism.

Baker BA, Mercer RR, Geronilla KB,. Kashon ML, Miller GR, .Cutlip RG (In press). Impact of SSC repetition number on muscle performance and histological response. Medicine and Science in Sports and Exercise.

Dong RG, Dong JH, Wu JZ, Rakheja S (in press). Available on-line since Dec. 12, 2006). Modeling of biodynamic responses distributed at the fingers and the palm of the human hand-arm system. J. of Biomechanics.

Krajnak K, Waugh S, Wirth O, Kashon ML (in press). Acute vibration reduced Aβ nerve fiber sensitivity and alters gene expression in the ventral tail nerves of rats. Muscle & Nerve.

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